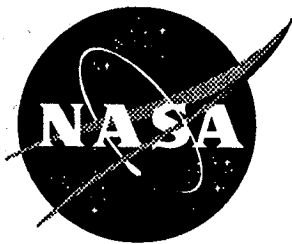


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The Flight Track Noise Impact Model

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The Flight Track Noise Impact Model

SUMMARY

To meet its objective of assisting the U.S. aviation industry with the technological challenges of the future, NASA must identify research areas that have the greatest potential for improving the operation of the air transportation system. Therefore, NASA seeks to develop the ability to evaluate the potential impact of various advanced technologies. By thoroughly understanding the economic impact of advanced aviation technologies and by evaluating how these new technologies would be used within the integrated aviation system, NASA aims to balance its aeronautical research program and help speed the introduction of high-leverage technologies. To meet these objectives, NASA is building an Aviation System Analysis Capability (ASAC).

NASA envisions the ASAC primarily as a process for understanding and evaluating the impact of advanced aviation technologies on the U.S. economy. ASAC consists of a diverse collection of models, data bases, analysts, and other individuals from the public and private sectors brought together to work on issues of common interest to organizations within the aviation community. ASAC also will be a resource available to the aviation community to perform analyses; provide information; and assist scientists, engineers, analysts, and program managers in their daily work.

The Flight Track Noise Impact Model (FTNIM) has been developed as part of the ASAC. Its primary purpose is to enable users to examine the impact that quieter aircraft technologies and/or operations might have on air carrier operating efficiency at any one of 8 selected U.S. airports. The analyst selects an airport and case year for study, chooses a set of flight tracks for use in the case, and has the option of reducing the noise of the aircraft by 3, 6, or 10 decibels. Two sets of flight tracks are available for each airport: one that represents actual current conditions, including noise abatement tracks, which avoid flying over noise-sensitive areas; and a second set that offers more efficient routing. FTNIM computes the resultant noise impact and the time and distance saved for each operation on the more efficient, alternate tracks. Noise impact is characterized in three ways: the size of the noise contour footprint, the number of people living within the contours, and the number of homes located in the same contours. Distance and time savings are calculated by comparing the noise abatement flight path length to the more efficient alternate routing.

The user develops the input, runs the case, and examines the output data table. The program is designed to be simple to run and may take from 5 minutes to an hour, depending on the complexity of the case.

Noise calculations are performed using the core modules of the FAA's Integrated Noise Model Version 4.11. Population and housing counts are computed using an algorithm that incorporates 1990 census data, modified to account for distributed population throughout the area and for nonresidential areas such as the airport property and nearby water bodies. The geographic information system is built on MAPINFO, a commercially available desktop mapping software package.

INTRODUCTION

This introduction reviews NASA's role and objectives for the aviation industry. Wyle Laboratories' research into the relationship between noise abatement and airline efficiency is outlined, describing the proposed uses for the Flight Track Noise Impact Model (FTNIM). The second section describes in general terms how the model works. The third section provides a more thorough report of the program's flow and methodology. The fourth section is a sample case. Then, the final section offers conclusions and areas for possible future study.

NASA's Role in Promoting Aviation Technology

The United States has long been the world's leader in aviation technology for civil and military aircraft. During the past several decades, U.S. firms have transformed this position of technological leadership into a thriving industry with large domestic and international sales of aircraft and related products.

Despite its historic record of success, the difficult business environment of the recent past has stimulated concerns about whether the U.S. aeronautics industry will maintain its worldwide leadership position. Increased competition, both technological and financial, from European and other non-U.S. aircraft manufacturers has reduced the global market share of U.S. producers of large civil transport aircraft and cut the number of U.S. airframe manufacturers to only two.

The primary role of the National Aeronautics and Space Administration (NASA) in supporting civil aviation is to develop technologies that improve the overall performance of the integrated air transportation system, making air travel safer and more efficient, while contributing to the economic welfare of the United States. NASA conducts much of the basic and early applied research that creates the advanced technology introduced into the air transportation system. Through its technology research program, NASA aims to maintain and improve the leadership role in aviation technology and air transportation held by the United States for the past half century.

The principal NASA program supporting subsonic transportation is the Advanced Subsonic Technology (AST) program. In cooperation with the Federal Aviation Administration and the U.S. aeronautics industry, the goal of the AST program is to develop high-payoff technologies that support the development of a safe, environmentally acceptable, and highly productive global air transportation system. NASA measures the long-term success of its AST program by how well it contributes to an increased market share for U.S. civil aircraft and aircraft component

producers and to the increased effectiveness and capacity of the national air transportation system.

NASA's Research Objective

To meet its objective of assisting the U.S. aviation industry with the technological challenges of the future, NASA must identify research areas that have the greatest potential for improving the operation of the air transportation system. Therefore, NASA seeks to develop the ability to evaluate the potential impact of various advanced technologies. By thoroughly understanding the economic impact of advanced aviation technologies and by evaluating how those new technologies would be used within the integrated aviation system, NASA aims to balance its aeronautical research program and help speed the introduction of high-leverage technologies. To meet these objectives, NASA is building an Aviation System Analysis Capability (ASAC).

Goal of the ASAC Project: Identifying and Evaluating Promising Technologies

The principal goal of ASAC is to develop credible evaluations of the economic and technological impact of advanced aviation technologies on the integrated aviation system. These evaluations would then be used to assist NASA program managers to select the most beneficial mix of technologies for NASA to invest in, both in broad areas, such as propulsion or navigation systems, and in more specific projects within the broader categories. Generally, engineering analyses of this kind require multidisciplinary expertise, possibly using several models of different components and technologies, giving consideration to multiple alternatives and outcomes.

FTNIM Background and Purpose

During 1994, Wyle Laboratories ("Wyle") initiated a NASA-sponsored study to analyze the economic impacts of local noise restrictions on air carrier operations. The project goals included documenting which noise abatement measures have the most impact on the way airlines operate and assessing the potential economic value of quieter aircraft technologies.

In November 1994, Wyle provided a midpoint progress report entitled “Aircraft Noise Reduction and Air Carrier Efficiency—Interim Progress Report,” Wyle Research Report WR 94-31. The report documented the results of five distinct sub-studies regarding:

- ◆ how much time per flight would need to be saved in a typical schedule to add a flight at the end of the day,
- ◆ nighttime curfews,
- ◆ noise restrictions at European airports,
- ◆ the extent to which local communities can impact airport capacity at two airports, and
- ◆ fuel burn for inefficient noise abatement flight tracks at three airports.

Subsequent to the release of that report, Wyle conducted visits to four airlines and two airframe manufacturers to discuss the report findings and to solicit industry input. Wyle was interested in gathering feedback on two primary issues: Were the report results consistent with industry findings? And, was the information useful to industry representatives? Each of the organizations—American Airlines, Delta Air Lines, United Airlines, USAir, Boeing Commercial Airplanes and McDonnell Douglas Aerospace—indicated that their in-house studies confirmed Wyle’s results wherever there was a common study area.

Input from airlines and airframe manufacturers also showed that the Wyle study was useful, particularly the substudies related to noise abatement flight procedures. Their feedback confirmed the value of analyzing more airport flight patterns to identify potential savings in time and distance. They also expressed a keen interest in seeing Wyle develop a methodology for evaluating the impact that preferential runway use schemes (with associated ground movement inefficiencies) have on air carrier operating costs and profitability.

The Wyle study of aircraft noise reduction and air carrier efficiency is documented in their “Final Progress Report,” WR 96-19. Since that initial study, the Logistics Management Institute (LMI), with oversight from NASA Langley Research Center, expanded the scope of work and began developing a model to be integrated into ASAC. This model will help users examine the effects that new aircraft technology may have on the aviation industry. As part of the LMI team, Wyle was primarily responsible for data collection and coding of the model. LMI provided project management oversight and systems engineering responsibility.

Anticipated Use of the Noise Model

The current task has developed a tool that NASA researchers and others can use to examine the relationship between noise abatement flight tracks, airline operating efficiency, and noise impact. The computer model, FTNIM, has expanded upon the earlier flight track efficiency study and extended the analysis capability to 8 domestic airports.

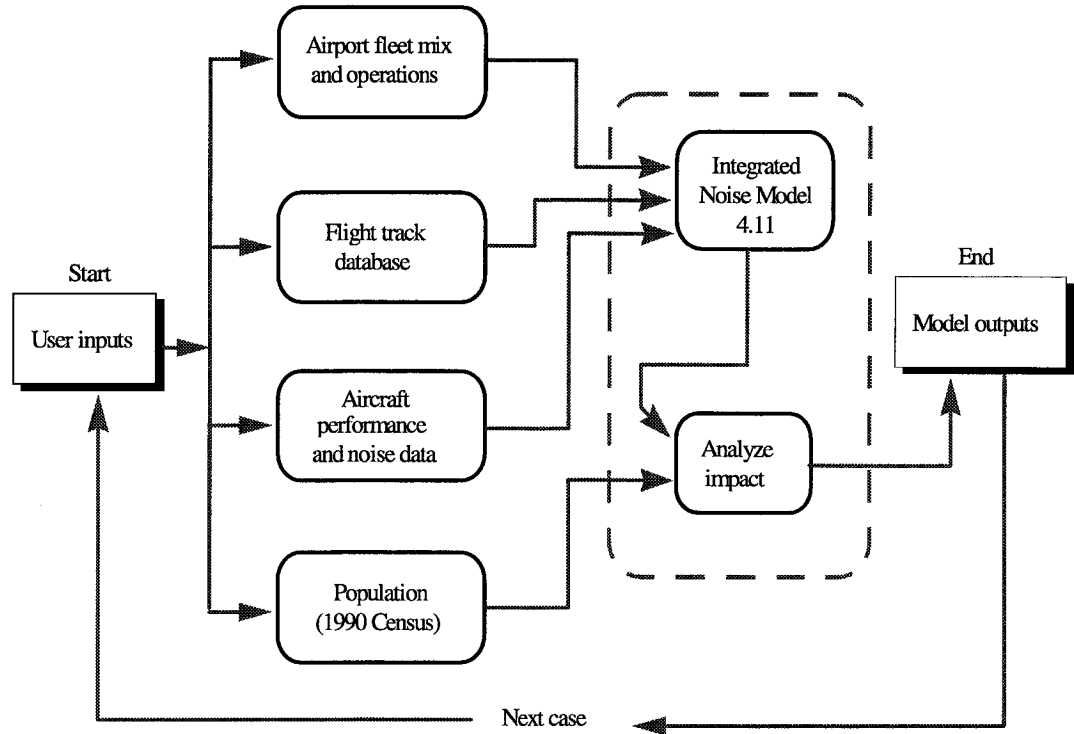
Using FTNIM, an analyst can answer the question: “How could airline operating efficiency be improved if noise were not a problem at this airport?” To facilitate this analysis, FTNIM provides an in-depth identification of the existing noise abatement flight procedures, enables the user to model quieter aircraft, offers alternative tracks that are more efficient, and assesses the community noise impact that results when the quieter airplanes use the more direct flight routes. By exercising FTNIM for successive cases, analysts can determine how much quieter the noise source (one or more specific aircraft types) must be to hold the noise impact constant, or even reduce it, while simultaneously improving airline operating efficiency.

The hardware and software required to run either the Windows 95 or the Windows NT version of FTNIM are specified in Appendix A.

OVERVIEW OF MODEL CAPABILITIES AND ACTIONS

The FTNIM accesses groups of data, gathers and processes the information needed to analyze the user’s case, executes two distinct computational actions, and documents the results along with a case history. Each of these functions—database access, case development, computation, and results output—are outlined below and are depicted in Figure 1.

Figure 1. Flight Track Noise Impact Model Flowchart



Database Access

FTNIM operates on four types of data derived from the sources noted in the Table 1.

Table 1. Data Types and Sources

Data type	Source
Airport fleet mix and operations	ASAC (shared information)
Flight track database for each airport	Wyle Laboratories
Aircraft performance and noise data	FAA - Integrated Noise Model
Population and housing	1990 U.S. Census

Case Development

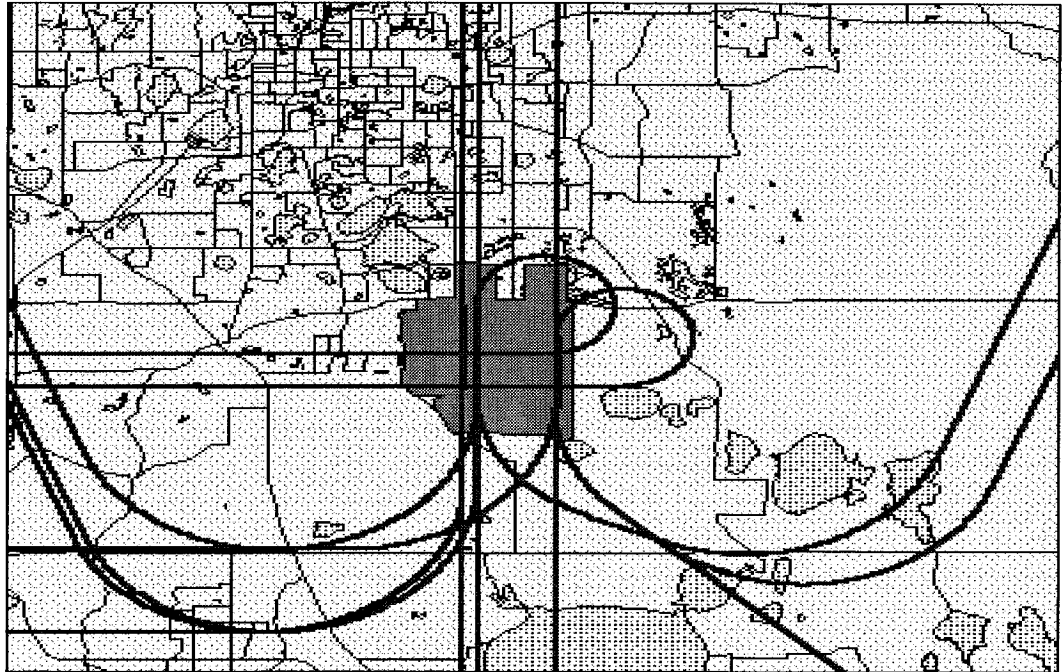
To develop a scenario, the user chooses one of the three case years for which operations data are available (1993, 2005, or 2015) and selects one of the following 8 airports:

- ◆ Cincinnati/Northern Kentucky International Airport (CVG)
- ◆ Detroit Metropolitan Wayne County Airport (DTW)
- ◆ General Edward Lawrence Logan International Airport (BOS)
- ◆ Greater Pittsburgh International Airport (PIT)
- ◆ Minneapolis—St. Paul International Airport (MSP)
- ◆ Orlando International Airport (MCO)
- ◆ Seattle—Tacoma International Airport (SEA)
- ◆ Washington Dulles International Airport (IAD)

Once the airport and case year have been selected, FTNIM lists the runways for that facility and allows the user to select which noise abatement flight tracks will be replaced with optimized tracks. Each alternate flight track has been developed for more direct routing. The time and distance savings associated with each efficient track are stored in the model database for future use.

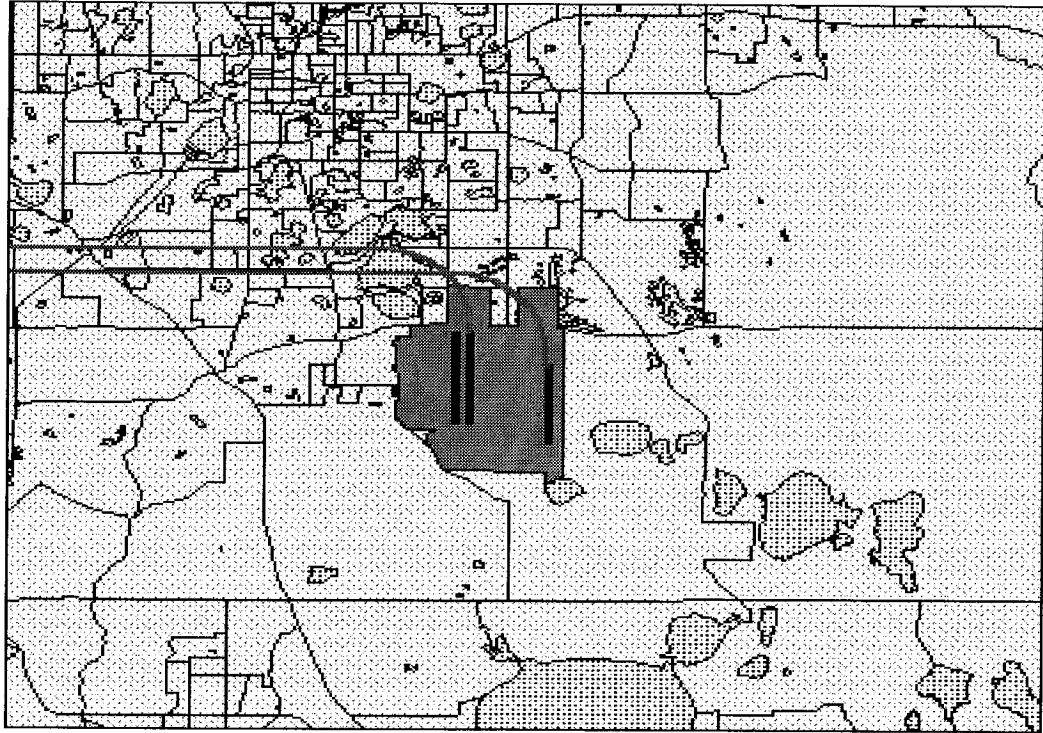
Scrutiny of flight procedures at most airports reveals that moving flight tracks brings up several airspace management issues. For example, with three large airports sharing the same airspace, the New York Metropolitan Area has a very complex, high-density air traffic environment. A noise abatement flight track at Newark cannot simply be relocated without taking the traffic patterns at La Guardia and Kennedy Airports into account. In all cases, we exercised caution in defining alternative routes to ensure that these optimized tracks are realistic in terms of safety, aircraft performance and air traffic management. Figures 2 and 3 show sample noise abatement and optimized flight tracks for Orlando International Airport (MCO).

Figure 2. Existing Flight Tracks for Orlando International Airport



Note that in Figure 2 there are two flight tracks that execute a 270 degree turn when departing to the north. This routing avoids flying over the dense residential population of Orlando, immediately north of the airport. In Figure 3, these same tracks have been relocated to fly over Orlando. This saves time and fuel for the aircraft operator, but would only be acceptable to the community if the aircraft were quiet enough not to create adverse noise impacts.

Figure 3. Optimized Flight Tracks for Orlando International Airport



The number of operations for the case airport and year will be displayed for four categories of jet-powered commercial aircraft: wide- or narrow-body and short- or long-haul. In FTNIM, a long haul flight is 1,000 statute miles or more. The operations for each category of aircraft may be increased or decreased at the user's discretion. The number of flights by all other aircraft (propeller, general aviation, helicopters, and military) will be displayed but may not be changed.

The fleet mix for the facility and year are also displayed and the user may reduce the modeled noise level for any commercial jet aircraft type by 3, 6, or 10 decibels (dB). FTNIM also enables users to reduce the noise level of an entire category of aircraft (wide- or narrow-body, short- or long-haul) in one step and then go back and selectively change the noise-reduction factors for individual aircraft types.

Computation

FTNIM exercises two computational modules as part of the analysis. First, it calls the FAA's Integrated Noise Model (INM) to compute the noise impact for the user's scenario. Noise impact is defined with a set of noise contours at 60, 65, 70, and 75 dB day-night average sound level (DNL). DNL is the industry standard for evaluating noise impact, and it accounts for the number and type of flights as well as the fleet mix and flight tracks. Operations conducted between 10 p.m. and 7 a.m. are assigned a 10 dB penalty to reflect their greater intrusiveness. The noise contours show which areas around the airport experience the greatest noise and what that average noise level is. INM computes the area of each noise contour.

Second, FTNIM exercises a geographic information system (GIS) to compare the noise impact areas with the residential neighborhoods and count the number of homes and people within the noise contours. The GIS module also subtracts the airport property and bodies of water from the noise contour areas computed by INM to give an "off-airport" area of impact, in acres.

Results Output

Two types of output information are provided by FTNIM: (1) efficiency gains—the time/ distance saved for each operation on each optimized flight track and (2) measures of noise impact—the number of acres, people, and homes exposed to significant levels of noise from airport activities. The results are presented in tabular form and a user has the option of saving the case file comprised of the case scenario and the output data.

FLIGHT TRACK NOISE MODEL OPERATION

This section describes components of the Flight Track Noise Impact Model (FTNIM) components in more detail. It also explains how the components operate, both singly and together.

Model Components

Several distinct components are combined to provide the modeling capabilities available in FTNIM: the user interfaces, databases, and computational modules. Wyle created the user input and output interfaces using Visual Basic and C++ programming languages. Much of the database content is taken from external, verified sources and then reformatted for use by the model; some has been devel-

oped in-house. The analytical program modules for the Windows 95 version were written in Visual Basic; the Windows NT version was written in C++. In addition, modules are used from two outside sources: the core noise computation module of the FAA's Integrated Noise Model (INM), and MAPINFO, the geographic information system package. The various modules are linked through a series of subroutines that process and transfer the data at each stage.

User Interfaces

Analysts use FTNIM by accessing the model, building a case scenario, executing the case, and receiving the output results.

INPUT SCREEN

The input screen is shown in Figure 4. Following a point-and-click approach, the user selects the airport by its three-letter code at the top left of the screen and the case year at the top right. Once that selection is completed, the table of available runways on the right side is populated and the user selects those for which the flight tracks will be optimized. The upper left portion of the screen displays the four categories of aircraft; their numbers of operations may be scaled up or down. The center of the screen shows the aircraft in the fleet, which can be modified to reduce their noise by 3, 6, or 10 dB. A button near the bottom executes the analysis once the user is satisfied with the scenario.

Figure 4. Sample FTNIM Input Screen

The screenshot displays the FTNIM Input Screen with the following sections:

- Airport Code:** MCO (selected from a dropdown menu).
- Ops/Pop Year:** 1993 (selected), 2005, 2015.
- Aircraft Scaling:** Four sliders set to 100%: Wide Body Short Haul, Wide Body Long Haul, Narrow Body Short Haul, and Narrow Body Long Haul.
- Runway Optimization:** Two input boxes containing '36R' and '35L', with 'Optimize>>' and '<<Remove' buttons.
- Operations Numbers:** A button labeled 'Operations Numbers'.
- Time and Distance Savings:** A button labeled 'Time and Distance Savings'.
- Aircraft Noise Reduction:** A table listing aircraft types and their noise reduction settings.

Aircraft	Model	Series	Engine	Noise Reduction
F28	F28	FELLOWSHIP	all	Jet
75F	B757	(freighter)	200PF	Jet
DC9	DC9	all 10 & 20 series	Jet	Jet
735	B737	500	Jet	Jet
- Global Noise Reductions:** Two sections for 'Wide Body' and 'Narrow Body' aircraft, each with radio buttons for 0 dB, 3 dB, 6 dB, and 10 dB.

OUTPUT SCREEN

Output is provided in tables that give the user's choices for the scenario, the time and distance savings for each of the selected runway flight tracks, and the noise impact statistics. Figure 5 shows a typical output table with results for Orlando International Airport in 2015 with two runways optimized, all operations levels kept at their defaults, and the noise levels for narrow-body aircraft reduced by 10 dB. The time savings for each of two flight tracks—numbered 6 and 10—are 41 seconds and 39 seconds, respectively.

Figure 5. Sample FTNIM Output Screen

Flight Track Efficiency Scenario Report for:				MOO
Execution date		12-Nov-96		
Year				
2015				
Runways optimized				
36R				
35				
Noise reductions				
Narrow		10 dB		
Level	Population	Housing	Acreage	
60 DNL	1924	800	4387	
65 DNL	80	27	866	
70 DNL	1	1	63	
75 DNL	0	0	7	
Time and distance savings per operation per track				
Track	Time		Distance	
6	41 s		5.5 nm	
10	39 s		5.2 nm	

Databases

The FTNIM integrates data drawn from a variety of sources into a comprehensive library providing the following information:

From INM database, INM input files, or airport sources:

- ◆ 8 airports, their runways, height above sea level, and average temperature;
- ◆ the flight tracks used for arrivals and departures on each airport runway;
- ◆ flight track utilization statistics for each aircraft type;

- ◆ the typical descent profiles for each aircraft type and several climb profiles, depending on how heavily loaded the aircraft is with fuel (more fuel for longer flights); and
- ◆ noise data for each profile for each aircraft type.

The ASAC relational database provides data about the specific types of aircraft operating at each airport, the number of departures executed during 1993, the operations levels projected for 2005 and 2015, and the average stage length each aircraft flies at that facility.

From Wyle Laboratories:

- ◆ alternate flight tracks designed to provide greater operating efficiency compared to existing noise abatement flight procedures and the time and distance saved for each; and
- ◆ a table translating the types of aircraft noted in the *Official Airline Guides* (OAG) into the equivalent types recognized by the integrated noise model (INM).

From U.S. census and commercially available databases:

- ◆ population and housing densities surrounding each airport, subdivided geographically into census blocks; and
- ◆ information defining the airport boundary and nearby bodies of water.

Computational Modules

The two key computational modules in FTNIM are the FAA's Integrated Noise Model (INM) and Wyle's airport noise impact calculation module using the geographic information system MAPINFO.

INTEGRATED NOISE MODEL VERSION 5.0

The industry standard for analyzing noise impacts from aircraft operations around airports is the FAA's INM, currently in version 5.0. This model was originally developed in the early 1970s and has been upgraded several times since then. According to a recent FAA statement:

The model is used by over 700 organizations in 35 countries to study changes in noise impact from new or extended runways or runway configurations, new traffic demand and fleet mix, revised routings and airspace structures, alternative flight profiles and modifications to air traffic control procedures.

During the course of developing FTNIM, two versions of INM have been used. The prototype model used INM Version 4.11 because the source code for the computational modules of the program was available. The more recent INM version 5.0 was only available in the executable form, requiring the user to run the full INM implementation, rather than just the core noise calculation parts needed for FTNIM. Through a license agreement, however, the FAA recently provided Wyle with a copy of the source code for the core modules of version 5.0, and these eventually will be incorporated into the model. Discussions regarding the way FTNIM operates will refer to INM version 4.11, since the version 5.0 components have not yet been fully integrated and tested.

WYLE GEOGRAPHIC INFORMATION SYSTEM FOR ASSESSING NOISE IMPACT

Under a separate NASA contract, Wyle has developed a significant capability for improved noise impact assessment using geographic information system techniques. The methodology starts with the INM noise contours and census data, but it uses a population density distributed uniformly throughout the census block rather than assuming all people reside at the centroid of the census block. The algorithms also examine the surrounding land uses to discount the airport property and nearby bodies of water. The resultant assessment of the number of people and homes impacted is much more accurate than if the contour areas were applied directly to the population density defined for the census blocks.

FITNIM uses the desktop mapping software, MAPINFO, to integrate the noise level, land use, and census data into a comprehensive noise impact map that can be analyzed for the areas, population, and houses located within each of the contour bands for a given user scenario.

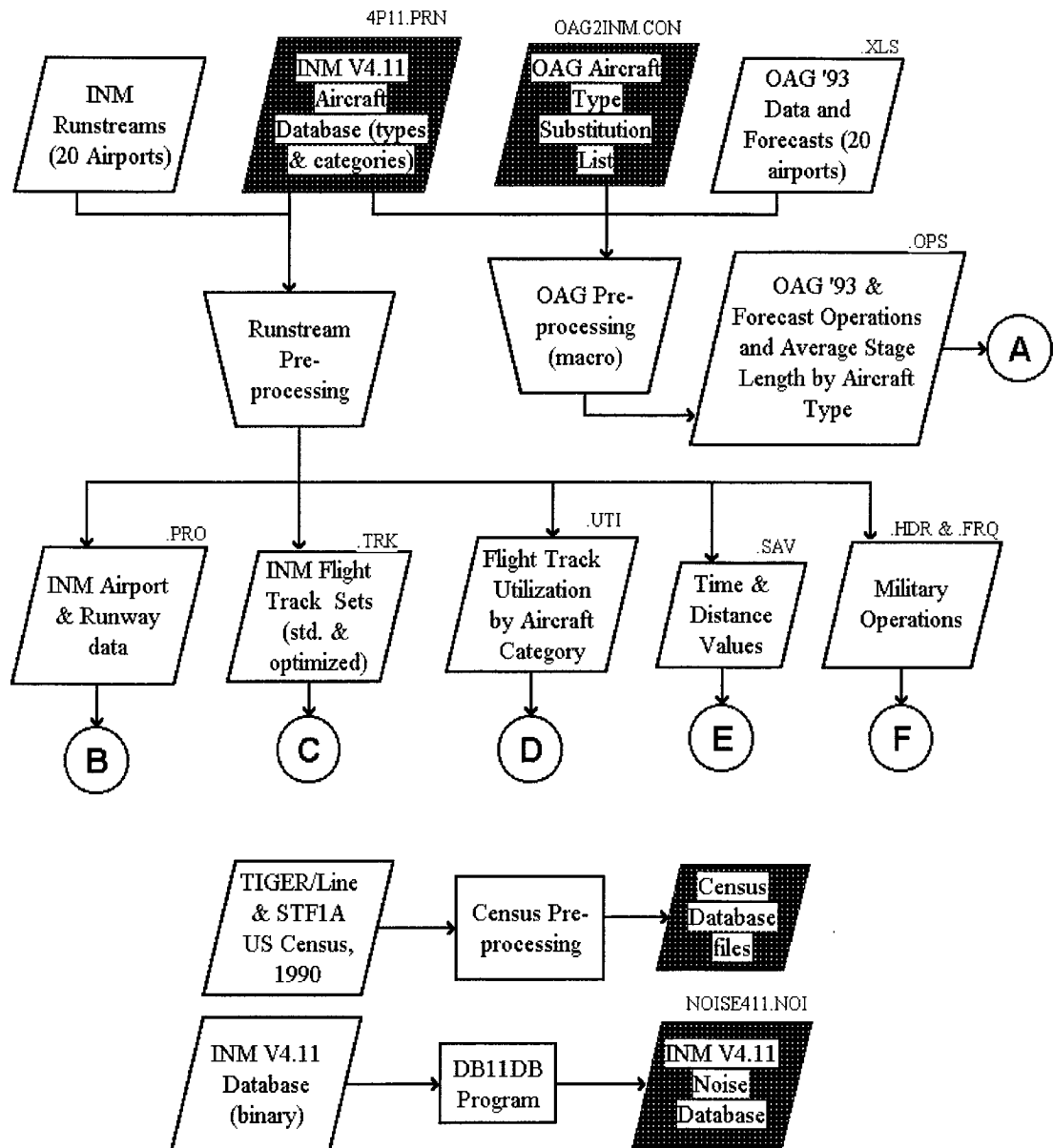
Connecting the Components

The connection and communication among the various components is accomplished through a set of customized routines that Wyle developed for FTNIM. The functions of these routines is quite varied, from data preprocessing and user-selection translation, to geographic mapping conversions.

Figure 6 shows the data flow for FITNIM. When the model is fully integrated into ASAC, the user will access the model through the ASAC server and make a series of choices, setting up the Client Case shown in the center, top portion of Figure 6. At this point in the process, the Client Case exists as a set of data selections. At each stage, routines are required to evaluate the user's scenario and collect the necessary data from the databases. Then, the required operations are performed on the data to prepare it for use by the next program module. A number of intermediate data files are created and used. (These actions are described more fully in the sample case.) All data groups and data tables appear in Figure 6 as parallelograms, while computational program elements are shown in rectangular boxes.

In Figure 6, the circled letters A through F indicate points in the analysis where data are provided by subroutines not shown in the figure. These actions, shown in Figure 7, preprocess the data for integration into the other program elements.

Figure 7. Data Preparation for the FTNIM



SAMPLE CASE

This section describes a sample calculation and the data on which the calculations are based. There are three subsections: the first describes the databases used to perform the calculations and the steps used to “pre-process” the data. The second contains the calculation steps. The third subsection discusses the accuracy of the model. All calculations described are for the current release of FTNIM, which uses INM version 4.11 (V4.11) rather than version 5.0.

Database Preparation and Data Preprocessing

There are four databases used in the entire process. Each one is described below. Data preprocessing consists primarily of the analysis of INM runstreams (input files) and OAG operations data.

INM AIRCRAFT TYPES AND CATEGORIES DATABASE (4P11.PRN)

The pertinent data in this file are the INM aircraft types from the V 4.11 database and their associated aircraft category. The two aircraft categories of “narrow body” and “wide body” have been established by the aviation industry.

Sample INM Version 4.11 Database File Section

INM_ACD	INM_NO	DESCRIPTION	OOS	CATNAME	NO#	NOINAME	NOISTAGE	Body	E/B	LDP_NAME	LDP_ID	0-500	500-1000	1000-1500	1500-2000	2500-3500
												TOP_S1	TOP_S2	TOP_S3	TOP_S4	TOP_S5
747100	1	B747-100/JT9D8D	OOS	JCOM	6	JT9D8D	1	W	4EWB	STD8D	1	1	2	3	4	5
747200	2	B747-200/JT9D-7		JCOM	7	JT9DFL	2	W	4EWB	STD8D	2	7	8	9	10	11
74710Q	3	B747-100Q/JT9D-7QIN		JCOM	7	JT9DFL	2	W	4EWB	STD8D	3	14	15	16	17	18
747SP	4	B747SP/JT9D-7		JCOM	7	JT9DFL	2	W	4EWB	STD8D	4	20	21	22	23	24
74720B	5	B747-200/JT9D-7Q		JCOM	50	JT9D7Q	3	W	4EWB	STD8D	5	27	28	29	30	31
DC820	6	DC-8-20/JT4A	OOS	JCOM	1	JT4A	1	N	4ENB	STD8D	6	34	35	36	37	38
707	7	B707-120/JT3C	OOS	JCOM	1	JT4A	1	N	4ENB	STD8D	7	40	41	42	43	44
720	8	B720/JT3C	OOS	JCOM	1	JT4A	1	N	4ENB	STD8D	8	46	47	48	49	50
707320	9	B707-320B/JT3D-7	OOS	JCOM	2	JT3D	1	N	4ENB	STD8D	9	51	52	53	54	55
707120	10	B707-120B/JT3D-3	OOS	JCOM	2	JT3D	1	N	4ENB	STD8D	10	58	59	60	61	62
720B	11	B720B/JT3D-3	OOS	JCOM	2	JT3D	1	N	4ENB	STD8D	11	64	65	66	67	68
DC850	12	DC-8-50/JT3D-3B	OOS	JCOM	2	JT3D	1	N	4ENB	STD8D	12	69	70	71	72	73
DC860	13	DC-8-60/JT3D-7	OOS	JCOM	2	JT3D	1	N	4ENB	STD8D	13	75	76	77	78	79
DC870	14	DC-8-70/CFM56-2C-5		JCOM	4	CFM562	3	N	4ENB	STD8D	14	82	83	84	85	86
BAE146	15	BAE 146-200/ALF502R-5		JCOM	5	ALF502R	3	N	4ENB	STD8D	15	89	90	91		
707QIN	16	B707-320B/JT3D-7QIN		JCOM	3	JT3DQ	2	N	4ENB	STD8D	16	92	93	94	95	96
DC8QIN	17	DC-8-60/JT8D-7QIN		JCOM	3	JT3DQ	2	N	4ENB	STD8D	17	99	100	101	102	103
CONCORO	18	CONCORDE/CLY593		JCOM	8	CLY593	1	N	4ENB	STD8D	18	106	107	108	109	110
DC1010	19	DC10-10/CF6-6D		JCOM	11	CF66D	3	W	3EWB	STD8D	19	112	113	114	115	116

OAG AIRCRAFT TYPE SUBSTITUTION LIST (OAG2INM.CON)

This file lists the OAG aircraft types and the comparable INM aircraft type on the basis of noise levels each aircraft generates. Wyle Laboratories and the FAA developed the substitution list (Table 2). OAG_A_Profile shown in column 3 indicates the departure climb profile used for each aircraft's operations. "STD3D" is the standard default climb procedure specified for each aircraft type. It defines engine thrust, climb gradient, and air speed as functions of the distance from the start of take-off roll.

Table 2. Sample OAG to INM Substitution List

OAG_Type	INM_Type	OAG_A_Profile	Description
310	A310	STD3D	Airbus A310 (all series)
320	A320	STD3D	Airbus A320
727	727Q7	STD3D	Boeing 727 passenger jet (all series)
72F	727EM2	STD3D	Boeing 727 freighter (200)**
733	737300	STD3D	Boeing 737-300
734	737400	STD3D	Boeing 737-400
743	74720B	STD3D	Boeing 747-300 SUD
744	747400	STD3D	Boeing 747-400
757	757RR	STD3D	Boeing 757 (all series)
75F	757RR	STD3D	Boeing 757-200pf freighter
763	767300	STD3D	Boeing 767-300/300ER
767	767CF6	STD3D	Boeing 767 (all series)

CENSUS DATABASE FILES (.TAB, .MAP, .ID, .DAT, .IND)

The FTNIM census database files contain three different sets of data: cartographic data, population data, and households data. To achieve this, three different databases have been combined and processed:

- ◆ TIGER/Line Census Files (1990, 1992, and 1995 releases), which provided the cartographic data;
- ◆ Census Summary Tape File 1a (STF1A), which provided the framework for the population and households data; and

-
- ◆ Woods & Poole Economics, Inc. 1994 Regional Forecast and Database, from which the actual population and households information were extracted.

The TIGER/Line database is a product of the United States Bureau of Census and consists of selected geographic and cartographic information extracted from the Census Bureau's TIGER database. For this project, only the cartographic information was needed. These data represent the structure definition of the polygonal shapes that when combined make up the Census areas of the different counties of interest. The criterion for selecting the counties was that they had to be located, even if only partially, within a 20-mile radius from the chosen airport. The degree of resolution of the resulting maps was chosen to be at the "block group" level since that is the maximum resolution common to all the types of Census data that were needed. A block group is a combination of census blocks that is a subdivision of a census tract or Block Numbering Area (BNA).

Once extracted, the selected TIGER/Line database data were refined by removing bodies of water and airport property from analysis. This step was necessary in order to obtain a more accurate representation of the actual population and households distribution and density after joining the population and households data with the cartographic data. If such refinement had not been done, the resulting map would have had population and households equally distributed between land and water, or airport property, where these happened to be included in the same block group. In the context of census data, households are defined as occupied housing units.

The 1990 Census STF1A is another product of the Bureau of Census containing data about all persons and housing units in the United States. The data extracted from this database was used, however, only to calculate the coefficients necessary to derive the population and households figures for each county block group from the county totals. This procedure was necessary because the Census Bureau provides forecasts for only a few years in the future and the database that contained required projections had only a county-level resolution. The population coefficients were calculated as follows:

$$Coeff_{POP} = \frac{BG_{POP}}{Cty_{TOTPOP}}$$

where:

$$\begin{aligned} \text{Coeff}_{POP} &= \text{Population coefficient} \\ BG_{POP} &= \text{Block group population figure} \\ \text{Cty}_{TOTPOP} &= \text{County total population figure} \end{aligned}$$

The households coefficients were also calculated in the same manner:

$$\text{Coeff}_{HOUS} = \frac{BG_{HOUS}}{\text{Cty}_{TOTHOU}}$$

where:

$$\begin{aligned} \text{Coeff}_{HOUS} &= \text{Households coefficient} \\ BG_{HOUS} &= \text{Block group households figure} \\ \text{Cty}_{TOTHOU} &= \text{County total households figure} \end{aligned}$$

The coefficients were then multiplied by the county total population and households data for the years 1993, 2005, and 2015 extracted from the Woods & Poole database giving resultant projected block group figures. This procedure assumes that while the population overall may change by some percentage, the *distribution* of population and households within each county will remain unchanged.

As previously stated, the last database used, the Woods & Poole Economics, Inc. 1994 Regional Forecast and Database, provided the projected data for the years 1993, 2005, and 2015. Woods & Poole used the corrected Census data from 1969 to 1992 as a starting point and then developed their forecast using a four-stage process.

First, the forecast for the entire United States was developed. This first projection was needed to provide a “control set” of data. Then, the United States was divided into 183 Economic Areas (EA) and employment and earnings projections were calculated for each of them. These forecasts were then used in the third stage as the principal explanatory variables used to estimate the population and households figures for each EA. The last stage repeated the process of the previous two stages to create forecasts at the county level. In this stage, the EA figures were used as control values. The main strength of this forecast technique lies in the comprehensiveness of the county database and the integrated nature of the

model. In fact, each change in one of the counties effects not only that county, but its neighboring counties as well.

Wyle had to extrapolate the analysis for several geographical areas, including Fairfax (VA), Fairfax City (VA), Falls Church (VA). Prince William County (VA), Manassas City (VA), and Manassas Park City (VA). These areas were grouped together in the Woods & Poole database, but not in the Tiger/Line or in the STF1A databases. As a result, to maintain a consistent dataset, coefficients had to be calculated in order to create datasets for each single area. The calculation of the coefficients was performed with the same technique used for the block group datasets. The equations used were the following:

$$AreaCoeff_{POP} = \frac{Area_{POP}}{Set_{TOTPOP}}$$

where:

$AreaCoeff_{POP}$ = Area population coefficient

$Area_{POP}$ = Area population figure

Set_{TOTPOP} = Set of areas total population figure

and

$$AreaCoeff_{HOUS} = \frac{Area_{HOUS}}{Set_{TOTHOUS}}$$

where:

$AreaCoeff_{HOUS}$ = Area households coefficient

$Area_{HOUS}$ = Area households figure

$Set_{TOTHOUS}$ = Set of areas total households figure

The data necessary to perform these calculation were extracted from the Census 1990 STF1A database.

INM NOISE DATABASE (NOISE411.DAT)

This file contains the Sound Exposure Level and Effective Perceived Noise Level values for slant range distances for all available V4.11 aircraft types as extracted from the FAA's INM database. The slant range distance is the straight line distance between the aircraft and the receiver grid point on the ground. For FTNIM, no attempt has been made to account for topographical features.

PREPROCESSING OAG OPERATIONS DATA

Operational data for each study airport were provided by LMI and contained the number of operations by OAG aircraft type for the years 1993, 2005, and 2015. For 1993 departures, the data also contain the average stage length in statute miles.¹

The spreadsheets are then processed with an Excel macro that, with the help of the INM Aircraft Types and Categories database and the OAG Aircraft Type Substitution List, lists the operations for 1993 and forecast years and, for departures, the average stage length by OAG aircraft type, sorted by the aircraft "classes." An aircraft class is defined as the combination of a quantitative descriptor of the stage length ("long-" or "short-"haul) and the aircraft category (narrow-body, wide-body, other). The "long" category is one having a minimum average stage length of 1,000 statute miles (equivalent to INM stage length 3). The Excel macro writes the .OPS file.

Sample .OPS File

```
"NARROW" , "LONG" , 1
"D93 " , 1200 , 3000 , 0 , 0
"WIDE" , "LONG" , 1
"744 " , 1200 , 3500 , 4240 , 6020
```

The sample shown above is for two aircraft, a McDonnell Douglas DC9-30 and a Boeing 747-460. The following information for the DC9 appears first in two lines; the classification as a narrow-body, long-haul aircraft; "1" for departures; type as a D93; average stage length of 1,200 statute miles; 3,000 annual operations in 1993; 0 operations in 2005; and 0 operations in 2015. Similar data are

¹ Stage length is defined as the great-circle distance from the airport of origination to the airport of destination.

given in the next two lines for the 747 indicating the same average stage length but increasing numbers of operations.

PREPROCESSING INM RUNSTREAMS

INM runstreams of typical operations for each study airport were obtained and analyzed through semiautomated and manual processes. The product of the pre-processing are up to six files for each airport. These six files are described in the following subsections.

INM Airport and Runway Data

The first three sections of each INM runstream containing the airport name/identifier, climatological information, and runway coordinates were extracted and written to the .PRO file.

Sample .PRO File

```
"AIRPORT" , "COM"  
"ALTITUDE" , 96 , "TEMPERATURE" , 23.0 , "C"  
"RUNWAYS" , 1  
"RW" , "36R" , "18L" , 50000 , 23000 , 50000 , 35004 , 359
```

For airport “COM,” the airfield altitude is given as 96 feet above mean sea level and the year-round average temperature is 23.0 degrees centigrade. COM has just one runway, designated 36R/18L, with one end point at coordinates (50000, 23000) and the other end point at coordinates (50000, 35004). The actual runway orientation is 359 degrees.

INM Flight Track Sets

For each modeled runway of each study airport, the flight tracks from the INM runstream were extracted. These are the “standard” flight tracks. Each flight track was studied for potential noise abatement modifications. If the flight track could be improved to fly a more direct route, the revised track is then considered an “efficient” flight track.

The guidelines used to determine the potential for modifying a modeled flight track for noise abatement include these:

- ◆ The INM flight track could be clearly associated with other published information an airport provided about its defined noise-abatement procedures. Most airports develop pilot instructions for flying noise abatement routes. These texts can be compared with the flight track shown in the INM runstream.
- ◆ A realistic, alternate route could be identified that would be safe, practical in terms of equipment performance, and would not infringe on other active airspace.
- ◆ The alternate track would provide measurable distance savings when compared to the existing noise-abatement track.

The standard and associated efficient flight tracks were written to the .TRK file for each study airport, sorted by runway. The sample file describes some of the flight tracks at COM. The first set of tracks shown is for operations departing from runway 36R. There are five existing abatement tracks called by numbers 2 through 6. The first track, number “2,” starts with a straight segment of 5.28 miles. Then, the track turns left 90 degrees through a turn radius of 1.74 miles. The final segment is straight for 50 miles, at which time the aircraft has left the airport’s vicinity. Note that the nonabatement track 2 is identical to the abatement track. For the file sample shown here, only track 6 differs between the abatement and non-abatement cases. The abatement procedure includes a turn to the right of 270 degrees, while the nonabatement case turns 90 degrees.

Sample .TRK File

```
"AIRPORT", "COM"
"DEPARTURES", 1
"36R", 1
"ABATEMENT"
"2", "STRAIGHT 5.28 LEFT 90 D 1.74 STRAIGHT 50"
"3", "STRAIGHT 5.28 LEFT 20 D 1.74 STRAIGHT 50"
"4", "STRAIGHT 1.97 RIGHT 20 D 1.74 STRAIGHT 50"
"5", "STRAIGHT 1.97 RIGHT 60 D 1.74 STRAIGHT 50"
"6", "STRAIGHT 1.97 RIGHT 270 D 1.74 STRAIGHT 50"
"NON-ABATEMENT"
"2", "STRAIGHT 5.28 LEFT 90 D 1.74 STRAIGHT 50"
"3", "STRAIGHT 5.28 LEFT 20 D 1.74 STRAIGHT 50"
"4", "STRAIGHT 1.97 RIGHT 20 D 1.74 STRAIGHT 50"
"5", "STRAIGHT 1.97 RIGHT 60 D 1.74 STRAIGHT 50"
"6", "STRAIGHT 1.97 LEFT 90 D 1.74 STRAIGHT 50"
"ARRIVALS", 1
"36R", 1
"ABATEMENT"
"B", "STRAIGHT 50"
"NON-ABATEMENT"
"B", "STRAIGHT 50"
```

Flight Track Utilization by Aircraft Class

Using a FORTRAN program, the operations in each INM runstream are grouped by class and summed within each class by flight track. The program then determines the percentage of the associated class' operations occurring on each flight track in daytime, evening (if applicable), or nighttime periods. For example, the program calculates, among all long-haul wide-bodied class of aircraft operations at airport COM, flight track 16 is used 82.1 percent during the daytime and 7.01 percent during the nighttime. The program writes the percentages (in decimal format) to the .UTI file.

Sample .UTI File

CLASS, TRACK, DAY, EVE, NITE
"LW", "16", " .821", " .00000", " .0701"

This sample file shows data for long-haul, wide-bodied aircraft (LW), on track number 16. The values shown indicate that 82.1 percent of the daytime LW flights use this track, no operations occur on it during the evening hours of 7PM to 10PM, and 7.01 percent of the nighttime LW operations use it from 10 P.M. to 7 A.M.

Time and Distance Values

The time spent and the distance traveled by aircraft that use the standard and efficient flight tracks are computed and written to a file. The time spent is computed by dividing the distance traveled in nautical miles by an average cruising speed. This cruising speed is specific to each airport and is computed as the weighted average of aircraft cruising speeds for the aircraft operating at the airport, with the weighting based on the number of daily departures. These data are kept in the .SAV file.

Sample .SAV File

"16","40.8","5.3"

As shown in this file, flight track 16 offers a savings of 40.8 miles and 5.3 seconds for every operation.

Military Operations

If military aircraft operations exist in the INM runstreams, their runstream header and frequency (operations) data are extracted and written to the .HDR and .FRQ files, respectively. This step is performed prior to determining the Flight Track Utilization by Aircraft Category. The FTNIM will hold military operations constant for all user scenarios.

Calculation Steps

With the databases and data preprocessing having been covered, it is now appropriate to describe the basic steps necessary to run a user-supplied operational scenario to compute noise-exposure and time/distance savings data.

SAMPLE SCENARIO

The following lists a (fictional) user-supplied operational scenario:

- ◆ Airport: COM
- ◆ Case Year: 2005
- ◆ Decibel Reduction by OAG type or Aircraft Category:

Aircraft Type	Reduction (dB)
Long Haul - Wide Body (LW)	0
Long Haul - Narrow Body (LN)	3
Short Haul - Wide Body (SW)	0
Short Haul - Narrow Body (SN)	0

- ◆ Scaling by Aircraft Category:

Class	Scaling
LW	125%
LN	150%
SW	0
SN	0

- ◆ Efficient Flight Tracks by Runway: Runway 36R only.

COMPUTING NOISE EXPOSURE DATA

The main goal of this task is to determine the off-base land acreage, number of dwellings, and population within the noise-exposure contours. This involves the creation of a runstream for the INM based on the user-supplied inputs. The INM then creates the noise-exposure contours that the GIS will use to determine noise

impacts. To accomplish the main goal, seven programs are executed: Header, Track, Noise, Onecase, INM, PNTREAD2, and Popcount. Each of these programs is described in the following seven subsections.

Header Program

The Header program determines the INM aircraft types associated with the user's case. It accomplishes this by reviewing the portion of the COM.OPS file (for the year 2005) and assigning the INM aircraft types via the OAG Aircraft Type Substitution List. Along with the COM.PRO preprocessed airport/runway data and the user case description (case year plus options), the list of aircraft types is compiled and written to the COM.HDR.

Sample COM.HDR File

```
BEGIN.  
SETUP:  
  TITLE <NASA ASAC HYPOTHETICAL CASE CREATED: 12/9/96  
3:18:15 PM>  
  AIRPORT <com>  
  ALTITUDE  96 TEMPERATURE  23 C  
FT.  
RUNWAYS  
  RW 36R-18L  50000  23000 TO  50000  35004 HEADING= 359  
AIRCRAFT:  
  TYPES  
    AC 747400 CURVE=74E  
    AC DC9Q9  CURVE=DC9
```

Track Program

The Track program requires two pieces of information: (a) the user-specified set of efficient flight tracks (standard tracks for all runways except runway 36R) and (b) the COM.TRK preprocessed file, which lists all standard and efficient flight tracks in semi-INM format for COM airport.

The Track program copies the appropriate set of tracks for the user case from the COM.TRK file to the COM.TRX file.

Sample COM.TRX File

```
"AIRPORT", "COM"
"DEPARTURES", 1
"36R", 1
"ABATEMENT"
"2", "STRAIGHT 5.28 LEFT 90 D 1.74 STRAIGHT 50"
"3", "STRAIGHT 5.28 LEFT 20 D 1.74 STRAIGHT 50"
"4", "STRAIGHT 1.97 RIGHT 20 D 1.74 STRAIGHT 50"
"5", "STRAIGHT 1.97 RIGHT 60 D 1.74 STRAIGHT 50"
"6", "STRAIGHT 1.97 RIGHT 270 D 1.74 STRAIGHT 50"
"NON-ABATEMENT"
"2", "STRAIGHT 5.28 LEFT 90 D 1.74 STRAIGHT 50"
"3", "STRAIGHT 5.28 LEFT 20 D 1.74 STRAIGHT 50"
"4", "STRAIGHT 1.97 RIGHT 20 D 1.74 STRAIGHT 50"
"5", "STRAIGHT 1.97 RIGHT 60 D 1.74 STRAIGHT 50"
"6", "STRAIGHT 1.97 LEFT 90 D 1.74 STRAIGHT 50"
"ARRIVALS", 1
"36R", 1
"ABATEMENT"
"B", "STRAIGHT 50"
"NON-ABATEMENT"
"B", "STRAIGHT 50"
```

Noise Program

The Noise program creates tables of sound exposure level and effective perceived noise level (noise curves) versus distance in the INM format for aircraft types associated with the aircraft class to which the user requests decibel reductions.

It accomplishes this by first assigning INM aircraft types and classes to the OAG aircraft types in the COM.OPS preprocessed file (for the year 2005) via the INM "aircraft types and categories" database and the "OAG aircraft type substitution list."

The Noise program then copies all the noise curves from the INM noise database applicable to the user's case (long-haul, narrow-bodied departures and narrow-bodied arrivals for our sample case), modifies them by the user's reductions (i.e., 3 dB), and writes the modified noise curves to the NOISE.DAT file in the INM format.

Onecase Program

The Onecase program has two primary functions: (a) It is the engine for computing the number of annual average daily daytime, evening, and nighttime operations by INM aircraft type, stage length (for departures) for applicable flight tracks on each runway, and (b) it compiles all INM operational data into an INM run-stream file.

Onecase computes operations with the Flight Track Utilization by Aircraft Class preprocessed file (COM.UTI), the user-specified scalings by aircraft class (125 percent for long-haul and wide-bodied aircraft, 150 percent for long-haul and narrow-bodied aircraft), the INM aircraft types and categories database, the OAG aircraft type substitution list, and the preprocessed COM.OPS file (year 2005 portion). A sample calculation is described below.

With the help of the INM aircraft types and categories database and the OAG aircraft type substitution list, the program determines that, for the year 2005, the COM.OPS file contains the following annual operations:

- ◆ 4,240 long-haul, wide-body departures consisting of only INM aircraft type 747400, stage length 5
- ◆ 624 long-haul, narrow-body departures consisting of only INM aircraft type DC9, stage length 3
- ◆ 4,240 wide-body arrivals consisting of only INM aircraft type 747400
- ◆ 624 narrow-body arrivals consisting of only INM aircraft type DC9.

The user-specified scalings would be applied to these annual operations (rounding to the nearest operations for the sake of brevity):

- ◆ $4,240 \times 1.25 = 5,300$ long-haul, wide-body (747400 stage length 5) departures
- ◆ $624 \times 1.5 = 936$ long-haul, narrow-body (DC9 stage length 3) departures
- ◆ $4,240 \times 1.25 = 5,300$ wide-body (747400) arrivals
- ◆ $624 \times 1.5 = 936$ narrow-body (DC9) arrivals.

Sample NOISE.DAT File

NOISE CURVES

NC DC9 6 BY 10 6 BY 10

EPNL

THRUSTS 3000 6000 8000 10000 12000 14000

200	92.6	98.4	102.7	107.2	111.8	116.8
400	88.4	94.2	98.5	103.2	107.8	112.9
630	85.1	90.9	95.3	100.0	104.7	109.9
1000	81.4	87.2	91.7	96.5	101.3	106.6
2000	75.4	81.2	85.8	90.6	95.7	101.2
4000	68.4	74.2	79.1	84.2	89.4	95.1
6300	63.1	68.9	74.0	79.5	85.0	91.0
10000	57.0	62.8	68.3	74.1	80.0	86.4
16000	49.5	55.3	61.3	67.6	74.0	81.0
25000	40.8	46.6	53.1	60.0	67.0	74.6

SEL

THRUSTS 3000 6000 8000 10000 12000 14000

200	88.6	93.8	98.3	103.0	107.8	113.1
400	84.8	90.0	94.6	99.2	104.1	109.4
630	81.9	87.1	91.7	96.5	101.4	106.8
1000	78.8	84.0	88.7	93.5	98.5	104.0
2000	73.8	79.0	83.7	88.6	93.6	99.1
4000	67.4	72.9	77.7	82.6	87.8	93.4
6300	63.0	68.2	73.1	78.1	83.3	89.0
10000	57.6	62.8	67.8	73.0	78.2	84.1
16000	51.2	56.4	61.6	66.9	72.4	78.4
25000	44.2	49.4	54.8	60.3	66.1	72.4

NC 747 5 BY 10 5 BY 10

EPNL

THRUSTS 8000 16000 24000 32000 40000

200	100.9	106.6	110.3	112.6	114.6
400	96.2	101.9	105.7	108.0	110.0
630	92.4	98.1	102.1	104.5	106.5
1000	87.8	93.5	97.9	100.5	102.5
2000	79.4	85.1	90.1	93.5	95.0
4000	71.4	77.1	83.2	86.5	88.5
6300	65.9	71.6	77.7	81.1	83.1
10000	59.7	65.4	71.6	75.0	77.0
16000	52.2	57.9	64.9	68.7	70.7
25000	43.3	49.0	57.1	61.4	63.4

SEL

THRUSTS 8000 16000 24000 32000 40000

200	96.3	100.3	103.4	105.8	107.8
400	91.8	95.8	99.1	101.4	103.4
630	88.3	92.3	95.7	98.1	100.1
1000	84.5	88.5	92.0	94.5	96.5
2000	78.4	82.4	86.2	88.9	90.9
4000	71.7	75.7	79.8	82.7	84.7
6300	66.9	70.9	75.2	78.2	80.2
10000	61.3	65.3	69.9	73.1	75.1
16000	54.7	58.7	63.7	67.1	69.1
25000	47.3	51.3	56.8	60.5	62.5

The COM.UTI file specifies that, for long-haul, wide-bodied aircraft, departure flight track 16 is used 82.1 percent during the daytime and 7.01 percent during the nighttime. For the long-haul, wide-body departures, departure flight track 16 would contain the following annual average daily operations:

- ◆ $(5,300 \text{ departures/year} \times 0.821) / (365 \text{ days/year}) = 12 \text{ daytime } 747400$
stage length 5 departures per day
- ◆ $(5,300 \text{ departures/year} \times .0701) / (365 \text{ days/year}) = 1 \text{ nighttime } 747400$
stage length 5 departures per day

Similar calculations would be made for the DC9 stage length 3 departures on flight track 16 and for all the arrivals on their flight tracks.

The program then combines the computed operations data with the

- ◆ COM.HDR file,
- ◆ COM.TRX file,
- ◆ NOISE.DAT file,
- ◆ COMMIL.HDR file, and
- ◆ COMMIL.FRQ file.

It generates an INM runstream file COM.INP. The COM.INP file is temporarily renamed to FOR02.DAT for purposes of executing the INM.

Integrated Noise Model Version 4.11

The Input, Flight and Compute modules of the INM are executed. The primary outputs are the FOR03.DAT and FOR33.DAT files, which contain the noise contours in a binary format.

PNTREAD2 Program

The PNTREAD2 program stands for “point read.” It reads the binary format contour files generated by the INM and writes GIS noise contour files compatible with MAPINFO.

Popcount Program

The Popcount program uses the “point read” files and the preprocessed Census database files to compute the off-airport land acreage, numbers of dwellings, and population within each noise-exposure contour.

COMPUTING TIME/DISTANCE SAVINGS DATA

The Savings program uses the preprocessed data file of “time and distance values” for all standard and efficient flight tracks (for COM airport) and the user-specified set of efficient flight tracks (tracks on runway 36R only.) The program computes the difference in time and distance between activation of the standard and efficient flight tracks and writes the results to the COM.SAV file, similar to the sample .SAV file shown previously.

Model Accuracy and Limitations

FTNIM relies on accurate input data, as do all computer models, and it makes as few assumptions and approximations as possible, given the intended use of the results. The primary usefulness of FTNIM is in its ability to model how *changes* in aircraft noise levels and/or flight procedures could affect flight efficiency and community noise impact. The assumptions and approximations noted below have been allowed because they speed processing time without diminishing, in the developer’s view, the utility of the model for its intended purpose. Overall, it must be noted that the noise calculations, while using the INM, are not sufficiently detailed to be useful for predicting noise impact at any given airport.

The definition of a long-haul flight as anything greater than 1,000 statute miles and the grouping of aircraft into long-haul versus short-haul categories is not as refined as most INM runstreams used for airport noise studies. However, the results of comparing one scenario to another are still valid for the level of detail available to most aviation industry and for research analysts concerning experimental and concept aircraft technologies.

Similarly, there are considerable differences in the noise characteristics of the various aircraft within the categories “narrow body” or “wide body.” New technologies are likely to be aimed at specific aircraft rather than broad categories.

The INM itself has certain limitations due to the simplified treatment of how aircraft noise is generated and propagated in air and across varied terrain. Generally, the model is considered accurate within approximately one decibel when groups

of aircraft are considered. The accuracy diminishes as the aircraft travels farther away from the airport and as there are fewer aircraft in the mix.

CONCLUSIONS AND PROPOSED FUTURE EFFORTS

The Flight Track Noise Impact Model (FTNIM) provides analysts with a convenient tool bringing together three basic functions for studying airports:

- ◆ evaluation of the time and distance savings associated with using more efficient flight procedures compared to existing noise abatement flight tracks;
- ◆ the industry standard noise modeling tool for aircraft operations; and
- ◆ accurate evaluation of changes in the number of people and homes impacted by noise resulting from user-defined changes in flight patterns, numbers of operations, and aircraft noise levels.

FTNIM has been presented at several meetings, at both the NASA Langley and NASA Ames Research Centers, at a Pratt & Whitney industry working group, and at McDonnell Douglas' Long Beach facility. The model has been well received and has generated considerable interest in the aviation community, both domestically and internationally.

To improve current FTNIM capabilities, Wyle and LMI have been discussing the following possible work tasks:

Add Airports to the Database

The current selection of 8 airports should be supplemented with 12 more. The domestic airports to be added will be

- ◆ Chicago—O'Hare International Airport (ORD)
- ◆ Dallas—Fort Worth International Airport (DFW)
- ◆ John F. Kennedy International Airport (JFK)
- ◆ La Guardia Airport (LGA)
- ◆ Los Angeles International Airport (LAX)

-
- ◆ Miami International Airport (MIA)
 - ◆ Newark International Airport (EWR)
 - ◆ Philadelphia International Airport (PHL)
 - ◆ Phoenix Sky Harbor International Airport (PHX)
 - ◆ San Francisco International Airport (SFO)
 - ◆ Washington National Airport (DCA)
 - ◆ William B. Hartsfield—Atlanta International Airport (ATL)

Improve Noise Analysis

Wyle Laboratories suggests reevaluating how FTNIM reduces the aircraft noise by 3, 6, and 10 dB. There are two ways to model reduced noise: either at the noise source or at the receiver location. The current method modifies the INM noise data files for the aircraft types and reduces the value of each segment of the source noise curve by the selected amount. However, it may be more accurate (and credible) to reduce the noise when it is computed at the ground (receiver). Within INM, the noise for each aircraft is computed at a grid of points on the ground. Then, the noise energies for all the aircraft are combined to compute the total noise impact at each grid point for all airport operations.

Applying the user-selected noise reduction at the receiver location would require modifying the grid of noise data points for each aircraft type. The benefit of this approach is that it makes no assumptions about how the noise is generated at the aircraft or how it is propagated from the aircraft to the ground. Sound generation and propagation are the two most complex phenomena the model addresses. The difference in accuracy may not be significant, but Wyle recommends performing a sensitivity analysis to verify this. Furthermore, since foreign airports often use models other than INM to generate their noise contours, it would make the model more flexible if future versions enable importing user noise contours rather than running INM.

Allow the User to Input Aircraft Noise Data Files

To increase the model's utility for examining the effect of integrating new aircraft technology into the marketplace, it would be helpful to modify FTNIM to accept user-defined noise data for experimental or concept aircraft.

Bibliography

Wyle Research Report WR 94-31, *Aircraft Noise Reduction and Air Carrier Efficiency—Interim Progress Report*, Wyle Laboratories, Arlington, VA, November 1994.

Wyle Research Report WR 96-19, *Aircraft Noise Reduction and Air Carrier Efficiency—Final Progress Report*, Wyle Laboratories, Arlington, VA, June 1996.

Appendix A

Hardware and Software Requirements for FTNIM

WINDOWS 95

- ◆ Hardware:
 - IBM compatible 486 or better
 - 8 Mb RAM
 - VGA Monitor or better
 - Mouse or other pointing device
 - 80 Mb hard disk space
- ◆ Software:
 - MapInfo Professional 4.X

WINDOWS NT 3.51

- ◆ Hardware:
 - IBM compatible 486 or better
 - 8 Mb RAM
 - VGA Monitor or better
 - Mouse or other pointing device
 - 80 Mb hard disk space
- ◆ Software:
 - MapInfo Professional 4.X

Appendix B

Glossary

ASAC	=	Aviation System Analysis Capability
DNL	=	Day-Night Average Sound Level
EA	=	Economic Areas, U.S. Census
FTNIM	=	Flight Track Noise Impact Model
GIS	=	Geographic Information System
INM	=	Integrated Noise Model
OAG	=	Official Airline Guides

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13. ABSTRACT (Maximum 200 words) To meet its objective of assisting the U.S. aviation industry with the technological challenges of the future, NASA must identify research areas that have the greatest potential for improving the operation of the air transportation system. To accomplish this, NASA is building an Aviation System Analysis Capability (ASAC). The Flight Track Noise Impact Model (FTNIM) has been developed as part of the ASAC. Its primary purpose is to enable users to examine the impact that quieter aircraft technologies and/or operations might have on air carrier operating efficiency at any one of 8 selected U.S. airports. The analyst selects an airport and case year for study, chooses a set of flight tracks for use in the case, and has the option of reducing the noise of the aircraft by 3, 6, or 10 decibels. Two sets of flight tracks are available for each airport: one that represents actual current conditions, including noise abatement tracks, which avoid flying over noise-sensitive areas; and a second set that offers more efficient routing. FTNIM computes the resultant noise impact and the time and distance saved for each operation on the more efficient, alternate tracks. Noise impact is characterized in three ways: the size of the noise contour footprint, the number of people living within the contours, and the number of homes located in the same contours. Distance and time savings are calculated by comparing the noise abatement flight path length to the more efficient alternate routing.					
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